A NEMA Lighting Systems Division Document

White Paper on Outdoor Lighting Code Issues

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Setting Standards for Excellence

Outdoor Lighting Code Issues

This white paper is intended to educate and provide information related to outdoor lighting issues and quality lighting. Effective lighting design incorporates careful consideration of many variables including: overall visibility, safety and security, energy efficiency, light trespass, and environmental concerns such as sky glow or impacts on local wildlife. Many states and municipalities have, or are in the process of, developing outdoor lighting codes. When carefully constructed, these codes can help to reduce sky glow, light trespass onto adjacent properties, glare and energy consumption. Present legislation around the country includes a myriad of remedies including use of specific source types or wattages, pole height limitations, or requirements for full cutoff luminaires. In some cases, these remedies are not well defined and may not rectify the problem. Some codes can cause unintended results such as increases in energy usage that may result in increased air pollution. Some requirements also make it very difficult to ensure a safe and secure environment. This paper will identify specific lighting issues, explain the interaction of these lighting issues, define correct lighting terminology and provide straightforward technical guidance.

There are three basic outdoor lighting concerns that need to be evaluated depending on the location and type of application. The attached table defines these issues, what causes them, and in general terms how they can be prevented. Most often, there will be concerns with a combination of these issues. It is critical to understand the interrelationship of them and to be aware that the techniques used to address one may in fact have a negative impact on one or more of the others. In addition, there are no existing measurements defined to quantify sky glow. Until the lighting industry develops these measurement techniques, it is difficult to incorporate specific limits in a lighting code.

Careful evaluation of the objectives for an outdoor lighting code is imperative to ensure that code criteria promote quality lighting. The following items are often cited in outdoor lighting codes, but may result in unintended consequences:

1. Mandating the use of full cutoff instead of non-cutoff luminaires will reduce light emitted directly from the luminaire into the night sky. However, it may require the use of more lighting equipment resulting in increased overall cost and energy consumption.
2. The consequences of using mandated pole heights that are inappropriate for the application may result in poor uniformity. Excessively dark areas may compromise safety and security while excessively bright areas will increase sky glow due to light reflected from ground surfaces into the night sky.
3. The use of low pressure sodium lighting is often required in areas surrounding observatories because it can be easily filtered by observatory instrumentation. However, the characteristics of this source will result in a reduction in the ability to distinguish specific colors and contrast. These factors may impact nighttime visibility.

Effective design techniques for outdoor lighting include:

- Defining lighting criteria based on the demographics for the area. There are distinct differences in the lighting requirements between urban and rural areas. Many codes and guidelines reference these areas as “environmental zones”. Ensure that sufficient light levels accommodate the safety and security needs for the area.
- Confining projections of light and glare to within property lines.
- Using pole heights appropriate to the application.
- Utilizing a shield that minimizes the component of light above horizontal and glare when luminaires need to be tilted or aimed. Avoid tilting cutoff luminaires.
- Utilizing control systems to reduce light levels during inactive periods or at predetermined times late in the evening while maintaining sufficient lighting for safety and security. Roadway luminaires should not be switched off at night.
- Designing the spacing of poles such that the illuminance on the ground is uniform, thereby increasing safety and security, while minimizing reflected light into the night sky.
- Providing adequate vertical illuminance helps to provide better visibility of automobiles and pedestrians for increased safety and security.
- Defining illuminance targets based on IESNA recommended guidelines. Excessive illuminance levels may increase the likelihood of sky glow, light trespass and glare. Adaptation difficulties may exist when leaving a brightly-lighted area to the darker roadway. Use of excessive lamp wattage and specification of excessive illuminance wastes energy.

There are a number of resources available to provide information on quality outdoor lighting. It is desirable to seek input from lighting professionals or equipment manufacturers. Industry organizations that can also provide useful information include:

- Illuminating Engineering Society of North America (IESNA)
- International Association of Lighting Designers (IALD)
- National Council on Qualifications for the Lighting Professions (NCQLP)
- National Electrical Manufacturers Association (NEMA)

These organizations can help to identify the specific issues for your lighting needs, and understand the interrelationship of product and design criteria. In addition, the International Dark-Sky Association can provide information regarding outdoor lighting near or around observatories, or areas concerned with sky glow.

For further information regarding the information in this white paper, contact Kyle Pitsor, Industry Director, Lighting Systems Division, National Electrical Manufacturers Association, 703-841-3274, kyl_pitsor@nema.org.

Outdoor Lighting Concerns:

	What is it?	***What causes it?***	***How do I minimize it?***
Sky Glow **- or -** ***"Light Pollution"***	Sky glow is the haze or "glow" of light that surrounds highly populated areas and reduces the ability to view the night time sky. Sky glow is of particular concern in areas near observatories. Light emitted or reflected into the sky interferes with the ability of the observatory and the public to view the sky in an unobstructed manner.	The sky glow phenomenon is a result of light reflected from atmospheric particles such as fog, dust, or smog. It results from light entering the sky from outdoor lighting in these two ways: • Light emitted from a luminaire in a direction above the plane of the horizon. • Light emitted from a luminaire in a direction below the plane of the horizon but reflected from the surrounding surface, including the ground, towards the sky. The effect this has depends on the amount of light aimed to the reflective surface, the reflectivity of that surface and the angle of the light leaving the surface.	To minimize sky glow effects, appropriate lighting equipment and layout design should be utilized. • Turn off non-critical lighting late at night. Do not turn off roadway luminaires at night. • Limit the use of non-cutoff luminaires. • Select luminaires emitting little to no light above the plane of the horizon. • Utilize internal or external shielding that minimizes the component of light above horizontal when luminaires need to be tilted or aimed. • Design to appropriate light levels and space poles such that illuminance on the ground is uniform. Excessive illuminance will increase the reflected component of light into the sky and affect visual adaptation especially when driving from one area to another.
Light Trespass	Light trespass occurs when neighbors of an illuminated space are affected by the lighting system's inability to contain its light within the area intended. The most common form of light trespass is spill light, illuminating objects beyond the property boundaries. Light trespass has become an increasing concern as residences and commercial developments are constructed closer to each other. Light trespass may be more obtrusive during late hours at night.	A common cause of light trespass is the inappropriate selection, tilting or aiming of outdoor luminaires for the particular lighting task. Light trespass occurs when a luminaire emits too much light at high angles or projects light too far from where it is intended. Even luminaires that are designed to control their light output can be light trespass offenders when improperly applied within a lighting design.	Light trespass can be minimized through careful selection of lamp wattage, luminaire type, and placement. Appropriate reflector selection, aiming and shielding of the luminaires is critical to keep the projection of the light within property boundaries. When using floodlights or wallpacks in areas close to adjacent properties, select products that utilize advanced optical techniques to minimize light trespass. Noncutoff luminaires will not have a significant impact on light trespass if the light does not project far from the luminaire location.
Glare	Glare occurs when a bright source causes the eye to continually be drawn toward the bright image or the brightness of the source prevents the viewer from adequately viewing the intended target. Glare may create a loss of contrast or an afterimage on the retina of the eye reducing overall visibility. Two classifications of glare are ***discomfort glare*** and ***disability glare***. Discomfort glare does not necessarily keep the viewer from seeing an object but does cause a constant adaptation of the eye to the contrast of light levels that in turn may cause a sensation of discomfort. Disability glare occurs when the bright source causes stray light to scatter in the eye which causes the primary image on the retina to be obscured. It may prevent the viewer from seeing things of importance.	There are two distinct situations when glare occurs: 1. When a spot in the field of view is significantly brighter in contrast to the rest of the field of view. An example is when a bright direct or reflected lamp image is visible. 2. When a significant difference in light levels exists between adjacent areas. An example is when a person leaves a brightly lighted gas station and re-enters the roadway it may take minutes for the eyes to adapt to the lower lighting levels.	Full cutoff and cutoff luminaires can help prevent the direct image of a bright source and lower the intensity of the light at high angles. Luminaires may be equipped with louvers and/or exterior visors to prevent viewing a bright source at lower angles, though this may effect the spread of the distribution. Additionally the use of quality prismatic or opaque lens materials can spread the bright image over a larger area and reduce the brightness of the source. Maximum mounting heights are required for proper aiming of floodlight luminaires to reduce glare in an adjacent, unintended, field of view. It is important to conform to ambient light levels based on the environment of proposed installation. Even lighting designs intended to comply with local codes or master store specifications may need to be adjusted to accommodate the specific surrounding environment.

It is critical to understand the interrelationship of each of these issues and to be aware that the techniques used to address one issue may in fact have a negative impact on one or more of the other issues. The key to effective lighting design and outdoor lighting codes is to define the lighting equipment and design criteria that minimizes the causes of sky glow, light trespass and glare while still providing a comfortable, visually effective, energy efficient and safe / secure outdoor environment. Knowledgeable industry professionals or organizations can assist in helping to define code or design criteria that will result in an effective lighting solution.

DEFINITIONS:

Many existing codes utilize improper or inconsistent use of lighting terminology. The following definitions accurately describe lighting terminology often used in outdoor lighting codes. Where appropriate, a paraphrased definition is provided in plain English to supplement the technical definition.

Term	Paraphrased Definition	Technical Definition Based on IESNA
Candela (cd)	Unit describing the intensity of a light source in a specified direction. Sometimes incorrectly referred to as a "light ray".	The SI unit of luminous intensity, equal to one lumen per steradian (lm/sr).
Cutoff Full Cutoff	A light distribution where no light is permitted at or above a horizontal plane located at the bottom of a luminaire. There will be little to no light at the angles that are usually associated with glare. *See Figure 1.*	A luminaire light distribution where zero candela intensity occurs at an angle of 90 degrees above nadir, and at all greater angles from nadir. Additionally, the candela per 1000 lamp lumens does not numerically exceed 100 (10 percent) at a vertical angle of 80 degrees above nadir.
Cutoff	A light distribution where a negligible amount of light is permitted at a horizontal plane located at the bottom of a luminaire. Light above the horizontal plane at the bottom of the luminaire is not limited, but cutoff luminaires usually have very little light above the luminaire. *See Figure 2.*	A luminaire light distribution where the candela per 1000 lamp lumens does not numerically exceed 25 (2.5 percent) at an angle of 90 degrees above nadir, and 100 (10 percent) at a vertical angle of 80 degrees above nadir.
Cutoff Semicutoff	A light distribution where slightly more light is permitted at a horizontal plane located at the bottom of a luminaire than the cutoff distribution. Like cutoff, light above the horizontal plane at the bottom of the luminaire is not limited, but the . amount of light above the luminaire is relatively small. *See Figure 3.*	A luminaire light distribution where the candela per 1000 lamp lumens does not numerically exceed 50 (5 percent) at an angle of 90 degrees above nadir, and 200 (20 percent) at a vertical angle of 80 degrees above nadir.
Cutoff Noncutoff	A light distribution that can produce considerable light above the horizontal plane located at the bottom of a luminaire. *See Figure 4.*	A luminaire light distribution where there is no candela limitation in the zone above maximum candela.
Disability glare	Glare that is significant enough to keep a person from seeing adequately.	The effect of stray light in the eye whereby visibility and visual performance are reduced. A direct glare source that produces discomfort may also produce disability glare by introducing a measurable amount of stray light in the eye.
Discomfort glare	Glare that is bothersome to an individual.	Glare that produces discomfort. It does not necessarily interfere with visual performance or visibility.
Efficacy *(Luminous Efficacy)*	A measurement used to compare light output to power consumed. Efficacy is a ratio of lumens to watts and can be defined for bare lamps or for luminaires.	The quotient of total luminous flux emitted by the total power input.
Efficiency	A ratio of the light emitted from a luminaire to the light produced by the bare lamps.	The ratio of luminous flux (lumens) emitted by a luminaire to that emitted by the lamp or lamps used therein.
Glare *(see also disability glare or discomfort glare)*	Light that hinders or bothers the human eye.	The sensation produced by luminances within the visual field that are sufficiently greater than the luminance to which the eyes are adapted, which causes annoyance, discomfort, or loss in visual performance and visibility. Note: the magnitude of the sensation of glare depends upon such factors as the size, position, luminance of the source, number of sources and the luminance to which the eyes are adapted.
High Intensity Discharge (HID)	A family of electric-discharge light sources including Metal Halide, High Pressure Sodium, and Mercury Vapor lamps.	An electric-discharge lamp in which the light-producing arc is stabilized by wall temperature, and the arc tube has a bulb wall loading in excess of 3 W/cm^2. HID lamps include groups of lamps known as mercury, metal halide and high-pressure sodium.
High Pressure Sodium (HPS)	A HID light source that typically provides high efficacy, but poor color. Color rendering is better with HPS than LPS, but the source is still considered to be yellow by most people.	A high-intensity discharge (HID) lamp in which light is produced by radiation from sodium vapor operating at a partial pressure of about 1.33×10^4 Pa (100 Torr).
Illuminance (footcandle or lux)	A term that quantifies light striking a surface or plane at a point. It is expressed either in lumens per square foot (footcandles/the English unit) or lumens per square meter (lux/the metric unit). 1 footcandle = 10.76 lux	The areal density of the luminous flux incident at a point on a surface.
Lamp	A light bulb.	A generic term for a source created to produce optical radiation. By extension, the term is also used to denote sources that radiate in regions of the spectrum adjacent to the visible.
Low Pressure Sodium (LPS)	Considered a single-color light source (appears to be yellow in color and causes most other colors to be seen as gray or brown).	A discharge lamp in which light is produced by radiation from sodium vapor operating at a partial pressure of 0.1-1.5 Pa (approximately 10^{-3} – 10^{-2} Torr)

Luminaire *(Light Fixture)*	A complete lighting unit, often referred to as a "light fixture". A luminaire consists of the light source, optical reflector and housing, and electrical components for safely starting and operating the source.	A complete lighting unit consisting of a lamp or lamps and ballasting (when applicable) together with the parts designed to distribute the light, to position and protect the lamps and to connect the lamps to the power supply.

Lumen	The unit representing the quantity of light being produced by a lamp or emitted from a luminaire.	The luminous flux emitted within a unit solid angle (1 sr) by a point source having a uniform luminous intensity of 1 cd.
Luminance	A term that quantifies directional brightness of a light source or of a surface that is illuminated and reflects light. It is expressed as footlamberts (English units) or candelas/meters squared (Metric units). (*Note: footlambert is no longer a recognized unit by the IESNA.)*	The quotient of the luminous flux at an element of the surface surrounding the point, and propagated in directions defined by an elementary cone containing the given direction, by the product of the solid angle of the cone and the area of the orthogonal projection of the element of the surface on a plan perpendicular to the given direction.
Mercury *(Mercury Vapor)*	A HID light source that typically provides long lamp life, but poor color and low efficacy compared to other HID sources.	A high-intensity discharge (HID) lamp in which the major portion of the light is produced by a radiation from mercury operating at a partial pressure in excess of 10^5 Pa (approximately 1 atm).
Metal Halide	A HID light source that typically provides good color and high efficacy.	A high-intensity discharge (HID) lamp in which the major portion of light is produced by radiation of metal halides and their products of dissociation – possibly in combination with metallic vapors such as mercury.
Nadir	The point directly below the luminaire when the luminaire is pointed down (0-degree angle).	None.
Photo Control	The device that turns the luminaire on at dusk and off at dawn. Also called photo eye, photocell, and or control. Photo controls may contain a timer to turn luminaires off part way through the night.	None
Shielded, Partially Shielded or Fully Shielded	Sometimes used in reference to a luminaire that is provided with internal or external louvers, shields or visors to limit glare. Also used to refer to luminaires that are designed to control glare without the use of additional shields. "Shielded" and "Fully Shielded" are sometimes used in place of either "Cutoff" or "Full Cutoff". "Partially Shielded" is sometimes used in place of "Semicutoff". The cutoff classifications are the industry-accepted terminology.	None

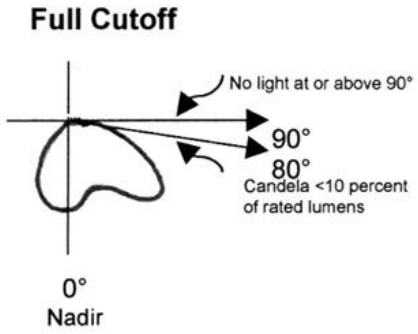

FIGURE 1

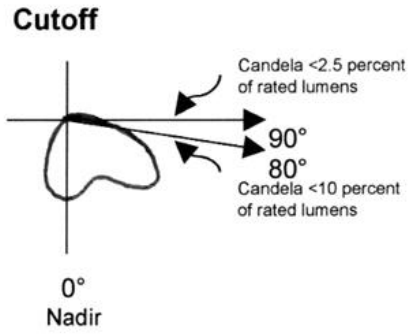

FIGURE 2

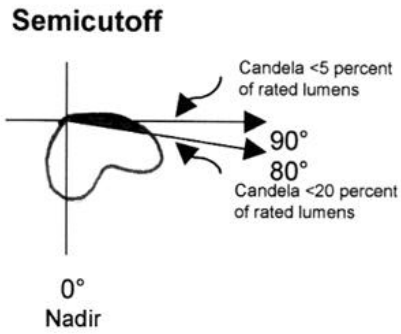

FIGURE 3

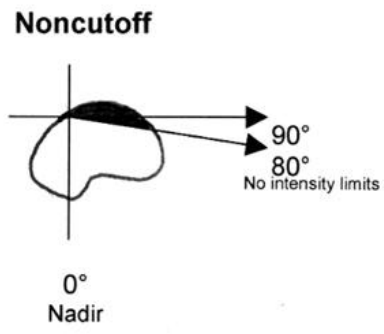

FIGURE 4

References:

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